219-121 CROSS REFERENCE SEARCH ROO

Dec. 11, 1962 C. W. HANKS 3,068,309
ELECTRON BEAM FURNACE WITH MULTIPLE FIELD GUIDANCE OF ELECTRONS
Filed June 22, 1960 3 Sheets-Sheet 1

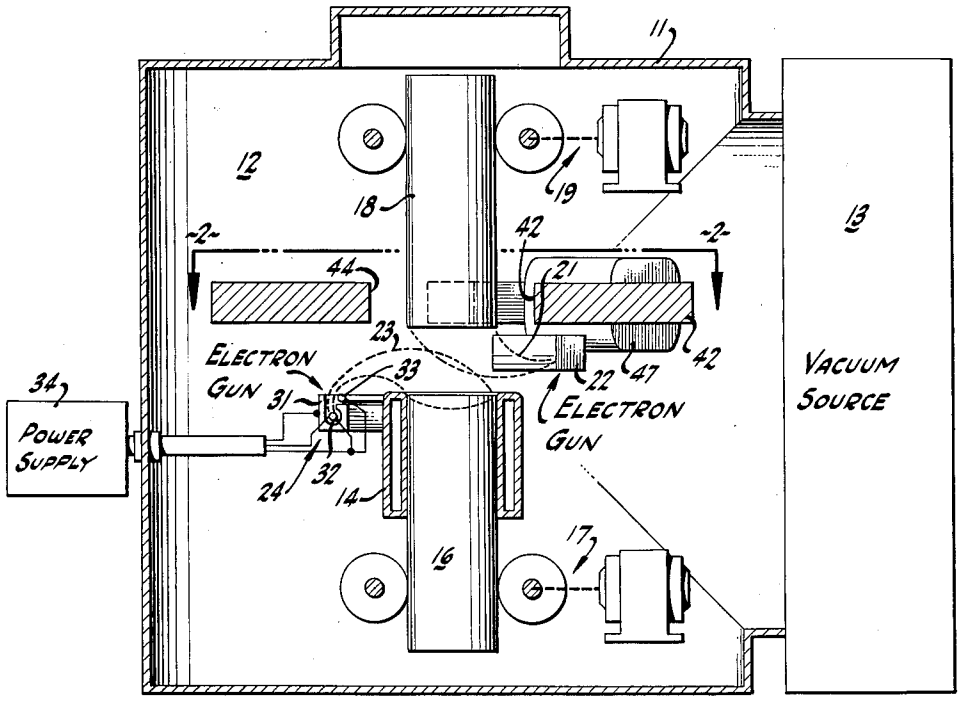


FIG-1

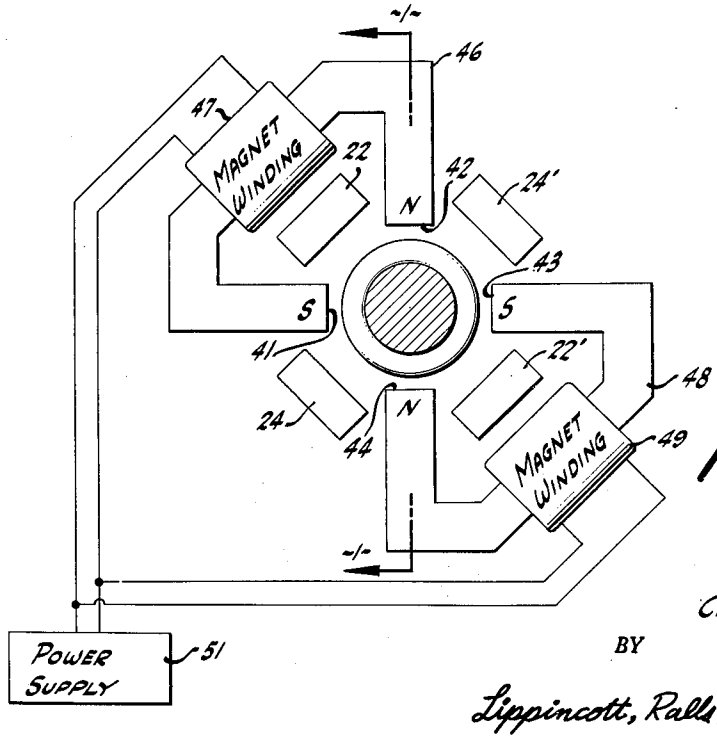


FIG-2

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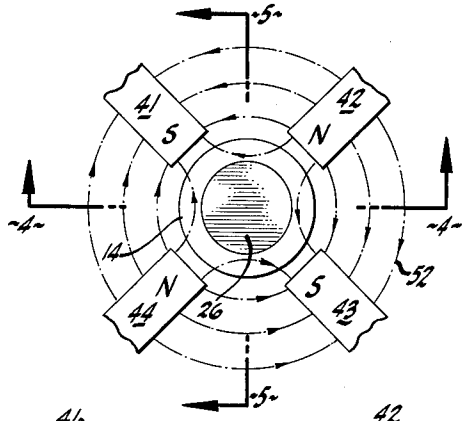
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ELECTRON BEAM FURNACE WITH MULTIPLE FIELD GUIDANCE OF ELECTRONS

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FIG-3



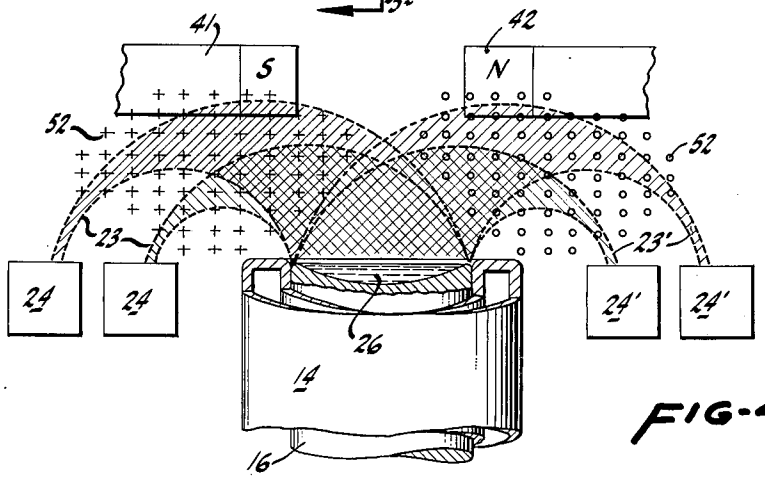


FIG-4

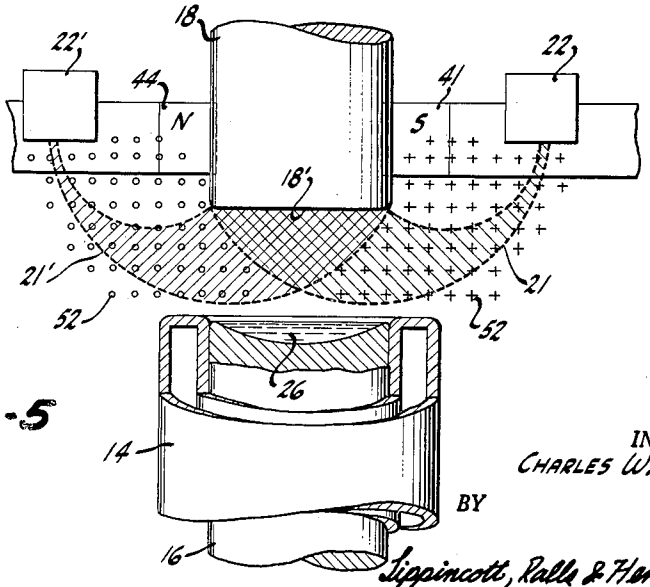


FIG-5

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ELECTRON BEAM FURNACE WITH MULTIPLE FIELD GUIDANCE OF ELECTRONS

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FIG-6

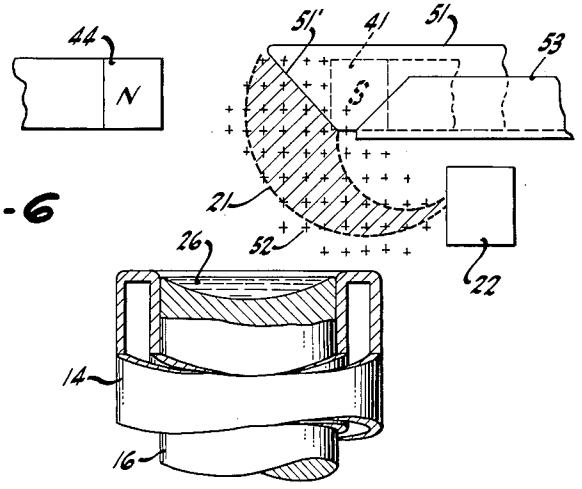
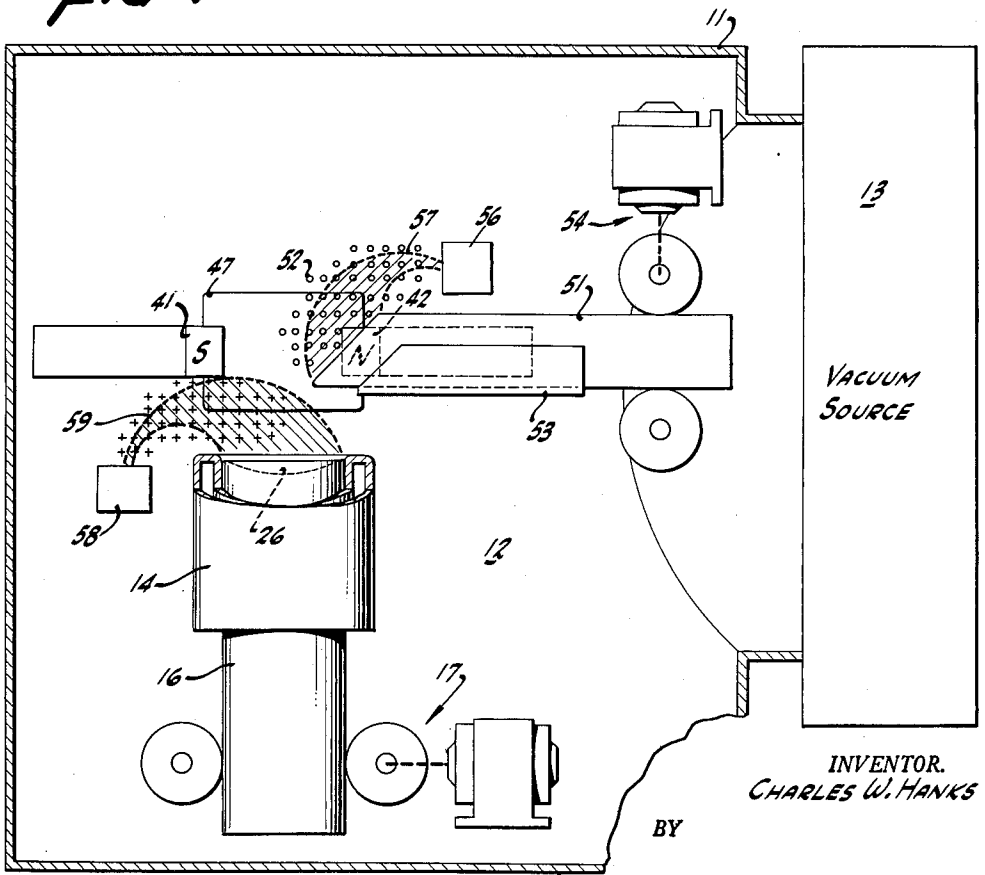


FIG-7



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3,068,309

ELECTRON BEAM FURNACE WITH MULTIPLE FIELD GUIDANCE OF ELECTRONS

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Filed June 22, 1960, Ser. No. 38,027
10 Claims. (Cl. 13—31)

The present invention relates to an improvement in electron beam furnaces, particularly as regards the magnetic guidance of electron beams therein. More specifically, the present invention provides in an electron beam furnace for the establishment of a multiplicity of curved magnetic fields serving to selectively guide high-energy electron beams of the furnace into focus upon material being treated therein.

An electron beam furnace includes an envelope which is continuously evacuated to the order of one micron of mercury, and adapted to contain materials for treatment, such as casting and purification. Within the furnace envelope there is provided a container, such as a water-cooled casting mold having an open top, and serving to receive molten metal for solidification therein. Bar stock of material to be treated is fed toward the furnace container above same, and such material is bombarded by high-energy electrons to thereby progressively melt the material so that same drips downwardly into the mold. It is further provided that the material in the container or mold shall be additionally heated by bombardment of the upper surface thereof with high-energy electrons, so as to maintain a skull or concave pool of molten material atop the ingot cast within the container. A continuous casting and purification process may be carried out with such a furnace by the continuous feed of bar stock toward the container for progressive melting of the material thereof and by the withdrawal of a solidified ingot from the bottom of the container, so as to thereby provide what may be termed an interrupted zone casting operation.

With regard to specific portions of the electron beam furnace, it is particularly noted that the material dripped into the container or mold is to be further heated from the top thereof to maintain a pool of molten material at the top of the solidifying ingot. This is particularly important for both casting operations and material purification operations, and the best results are normally attained by the utilization of a separate electron beam source for bombarding the pool of material in the container to impart the desired heat thereto. In the melting of material in an electron beam furnace, there is unavoidably generated a certain quantity of gas and vapor, which is rapidly removed by the continuous evacuation of the furnace chamber, but which, however, causes instantaneous pressure excursions which may prove highly deleterious to furnace elements subjected thereto. Both these pressure excursions and the presence of substantial quantities of vapor in the vicinity of the melting operation in the furnace will damage electron beam sources disposed immediately adjacent the metal being treated, and consequently, it is highly desirable to employ distant or remote electron guns, preferably positioned so that same are not affected by the gases and vapors evolved. It is further advantageous to employ such distant electron guns in order to achieve full electron acceleration remotely from the material being treated, in order that the electron beam shall not be undesirably deflected by the material itself, or by gases and plasmas which may surround same. Of further importance in the optimization of electron beam furnaces is the focusing of electron beams onto the material being melted in the furnace. Such focusing will be seen to provide for the

maximum utilization of the electron beam energy, and also to prevent undesirable damage to other portions of the furnace, which might otherwise be bombarded by such beams.

The present invention provides separate electron guns for directing bombarding electrons upon the bar stock to be melted, and into the pool of molten material in the container or mold of the furnace. The provision of separate guns, which may be denominated as bar guns and pool guns, provide a maximized degree of control over furnace operations, inasmuch as it is possible with multiple guns to thereby accurately and precisely control the amount of heat imparted to the bar stock being melted, as well as to the pool being further heated. By the utilization of a multiplicity of electron guns, it is also possible to achieve a very high-energy deposition from electron beam bombardment without exceeding normal electron gun output, inasmuch an the total energy deposited may then be the summation of energies from a number of separate guns of limited output.

The present invention further provides for the utilization of distant electron guns wherein the electron beams are raised to full velocity remotely from the area of electron bombardment, so that precise control over the electron beam trajectory may be achieved. Of even greater importance is the provision in the present invention of a particular magnetic field guidance for the electron beams, whereby it is possible for the electron guns to be so situated that they are entirely out of line with all materials being bombarded. The foregoing provides a maximized longevity of the gun cathodes, inasmuch as vapors and gases evolved in furnace operation cannot directly impinge upon the guns. In this respect it is noted that the bombardment melting of a melt stock or bar stock of raw material in the furnace will cause gas bursts to be evolved from the heated surface, and furthermore, that these gas bursts will move rapidly away from the surface, generally normal thereto. Consequently, the placement of any electron gun or source in line with the melting surface seriously endangers the source.

The present invention provides a multiplicity of curved magnetic guidance fields, which are quite simply generated and which serve to guide separate electron beams into quite different trajectories for the selective bombardment of the bar stock and of the pool of molten material in the container of the furnace. In accordance with this invention, there is provided a plurality of magnetic guidance fields, and this plurality serves to provide guidance of electron beams from positions of maximum gun safety and protection, as will become more apparent from the following description of the invention. Not only do the plurality of magnetic guidance fields hereof direct the trajectory of the bombarding electron beams, but furthermore, these fields are so formed as to exert a focusing effect upon the electron beams, and consequently, to direct a maximum portion of each beam upon the desired surface for bombardment of same.

Various objects and advantages of the present invention will become apparent to those skilled in the art from the following description of particular preferred embodiments of the invention; however, no limitation is intended by the terms of such description, and instead, reference is made to the appended claims for a precise delineation of the true scope of the present invention.

The invention is illustrated in the accompanying drawings, wherein:

FIG. 1 is an elevational view in section of an electron beam furnace embodying the present invention;

FIG. 2 is a plan view of the furnace of FIG. 1, taken in the plane 2—2 thereof;

FIG. 3 is a schematic representation of the magnetic

guidance means of one embodiment of this invention, and indicating the configuration and direction of the magnetic guidance fields;

FIG. 4 is a sectional view taken in the plane 4—4 of FIG. 3 and illustrating electron guns and electron beam trajectories for those beams bombarding the pool of molten material in the furnace container;

FIG. 5 is a sectional view taken in the plane 5—5 of FIG. 3, and illustrating electron guns and the trajectory of electron beams therefrom bombarding the bar stock for melting of same;

FIG. 6 is a partial sectional view through the central portion of an electron beam furnace, illustrating an alternative embodiment of the present invention, and taken in a plane corresponding to plane 5—5 of FIG. 3; and

FIG. 7 is an elevational view in section through an electron beam furnace and illustrating an alternative embodiment of the present invention.

There is illustrated in FIG. 1 an electron beam furnace including the modifications of one embodiment of the present invention, and referring thereto, it will be seen that the furnace includes an enclosure 11 defining an interior chamber 12, which is continuously evacauated to a pressure of the order of 1 micron of mercury by evacuation means 13 communicating with the chamber. Within the chamber 12 there is disposed a container or mold 14 for receiving material melted in the furnace. This mold 14 may be formed as a water-cooled, copper jacket, which is open at both the top and the bottom, so that material solidified therein by the removal of heat may be withdrawn as a solid ingot 16 from the bottom of the mold. Withdrawal means, generally indicated at 17 in the figure, are provided for slowly removing the ingot from the mold as same solidifies therein.

A melt stock or bar stock 18 is fed toward the open top of the mold or container 14, as by feed means 19, for progressive melting of such material so that same will drip downwardly into the top of the mold. Melting of the bar stock 18 is preformed by bombarding same with an electron beam 21 from an electron gun 22, and similarly, heat is added to the material within the mold 14 by bombardment of the upper surface of such material with an electron beam 23, generated by an electron gun 24. The addition of such heat to the material of the mold 14 will maintain a molten pool of material 26 atop the ingot 16 in the mold, and this serves to additionally purify the metal during casting operations.

The individual electron guns of the present invention may be relatively conventional in structure and operation, inasmuch as they are required only to generate and accelerate a directional beam of electrons to a high velocity remotely from the terminal point of the beam. An exemplary electron gun is illustrated in FIG. 1 as including a backing electrode 31 having a reentrant opening therein, and an electron-emissive filament 32 disposed in such opening. An anode or accelerating electrode 33 is disposed without the backing electrode 31 adjacent the opening therein for accelerating generated electrons from the gun, and defining same into a beam. Suitable energization of such an electron gun may be provided from a power supply 34 impressing a direct current accelerating potential between the backing electrode 31 and accelerating electrode 33, and also passing a heating current through the filament 32. Such a gun may, for example, operate at a voltage of 5 to 15 kv. The electron guns may also employ indirectly heated emitters and such guns have proven advantageous in the production of a highly directional beam. In the following description of the improved electron beam furnace of the present invention, the electron guns noted may have the configurations above described or any alternate configuration producing a high-energy focused electron beam.

With regard to the manner in which the present invention provides for directing the electron beams onto the bar stock 18 for melting same and into the open top of the mold 14 for maintaining the molten pool of material 26 therein, reference is made to FIG. 2 which, taken in conjunction with FIG. 1, illustrates a single, preferred embodiment of the magnetic guidance means of this invention. In accordance herewith, there are established a plurality of curved magnetic guidance fields extending circumferentially about and somewhat perpendicularly to the axis of the mold or container 14, and these fields may be generated between magnet pole faces 41, 42, 43 and 44. As shown in FIG. 2, the pole faces 41 and 42 may be provided upon a single magnet yoke 46, having a magnet winding 47 thereabout. The pole pieces 43 and 44 may be likewise disposed at opposite ends of a relatively C-shaped magnet yoke 48, having a magnet winding 49 thereabout. The above-noted pole piece are disposed in quadrature about the container 14, and the magnet windings 47 and 49 are energized as from a magnet power supply 51 in such a manner as to maintain diamertically opposed pole pieces of like magnetic polarity. The pole pieces may be located above or below the top of the container. As a consequence of this arrangement, there will be seen to be provided alternate magnet poles about the circumference of the container. Electron guns 22 and 22', adapted to bombard the bar stock, are disposed in opposite quadrants, and the electron guns 24 and 24', adapted to bombard the pool, are disposed oppositely in intermediate quadrants, so that about the circumferenence of the container the guns alternate as to the utility thereof.

With regard to the magnetic fields established by the quadrature arrangement of magnet pole faces, reference is made to FIG. 3, wherein the magnet poles are indicated by the same numerals employed above in connection with FIG. 2. There is included in the illustration of FIG. 3, dashed lines 52 indicating the magnetic lines of force existing in the area about the quadrature pole pieces, and it will be seen that there is established a somewhat annular or circumferential magnetic field which, however, alternates in direction in each quadrant. Thus, the magnetic field from the north pole 42 extends lines of force away from same toward each of the south poles 41 and 43, disposed some 90 degrees therefrom. Although this magnetic field will be seen to be directed generally circularly between the pole pieces so as to present a convex field from the exterior of the device, it will be further seen that immediately over the container or in the direct vicinity thereof, the magnetic field lines curve oppositely so as to present a concave magnetic field configuration from the exterior of the device. This particular magnetic field configuration is highly advantageous in the electron beam furnace of the present invention, as set forth in more detail below.

Referring now to FIG. 4 which is a sectional view through the central portion of the furnace and showing only the pole pieces 41 and 42, it will be appreciated that the magnetic field is directed into the plane of the figure at the left thereof toward the south pole 41, and is directed outwardly of the plane of the paper at the right of the figure from the north pole 42. These field directions are indicated by conventional symbols in FIG. 4, wherein the field into the paper is shown as small crosses, and out of the paper as small circles. As shown in FIG. 4, there are provided a plurality of electron guns adapted to bombard the pool of molten material 26 with high-energy electrons for heating this pool, and there may, for example, be employed a plurality of electron guns on each side of the mold 14. The two illustrated guns 24 to the left of the mold in FIG. 4 will be seen to be disposed below the upper surface of the pool, laterally outward of the mold and to each direct electron beams 23 upward into the magnetic field 52 having lines of force extending out of the plane of the figure. As charged particles traveling in a magnetic field are subjected to a deflecting force at right angles to the direction of velocity and the direction of the field, it will be appreciated that these electron

beams 23 are urged into a curved trajectory by such force. With the illustrated orientation of magnetic field direction and electron beam trajectory, such deflecting force will serve to curve the electron beams downwardly, as illustrated, into the top of the container 14. On the opposite side of the container, further electron beam sources 24' direct high-energy electron beams 23' generally upwardly into the magnetic field therein extending into the plane of the figure. With this relative reversal of magnetic field direction, it will be appreciated that the deflecting force exerted upon the electrons of the beams 23' will thus be opposite to that exerted on the beams 23, so that the electrons from sources 24' are urged to the left of the figure, and further application of this force as they pass through the magnetic field will serve to curve the beam trajectories downwardly into the top of the mold 14.

With this configuration of the magnetic guidance fields, it will be seen to be possible to provide for a multiplicity of electron guns adapted to bombard the material within the mold or container 14. The opposite direction of magnetic fields on the two sides of the container serve to deflect electron beams from both sides into the open top of the container. It is furthermore to be noted in connection therewith, that the electron beams 23 and 23' enter a convex magnetic field and pass through a concave magnetic field before reaching the open top of the mold. This magnetic field configuration acts somewhat as a magnetic lens to thereby focus the electron beams into the open top of the mold. This is highly desirable, inasmuch as those portions of the beams having velocity components laterally of the desired beam trajectory will be acted upon by the magnetic field to deflect same back into the desired trajectory. In the convex portion of the magnetic field through which the beams pass they are urged into a relatively planar beam, and in the latter portion of their trajectory into the mold they are spread somewhat by the concave portion of the magnetic field, so as to thereby bombard substantially the entire upper surface of the molten pool of material within the container. A very highly desirable focusing effect has been achieved with electron beam furnaces employing the magnetic guidance system hereinabove described.

With regard to the provision of electron beam bombardment for material to be melted in the furnace, and dripped into the container thereof, reference is made to FIG. 5 of the drawing. In FIG. 5, the pole pieces 41 and 44 are shown in the background with the bar stock 18 being fed vertically downward toward the open top of the mold 14 within the furnace. In the plane of FIG. 5, it will be appreciated that the magnetic field extends outwardly from the plane of the paper at the left of the figure and inwardly into the plane of the figure at the right thereof, as indicated by the conventional symbols employed in the illustration. Placement of the electron guns 22 and 22' laterally outward of the container 14 on opposite sides thereof and in the quadrants illustrated in FIG. 5, it will be seen to provide for the direction of electron beams 21 and 21' from these sources into magnetic guidance fields which exert deflecting forces upon the electrons of the beams so as to urge the beams into a curved trajectory extending upwardly so as to thereby terminate upon the lower leading edge of the melt stock or bar stock 18. Considering the electron beam 21 generated by the high-energy electron gun 22, same will be seen to be directed from the gun substantially perpendicularly into the magnetic field and note that such beam may originally travel downward if the field strength is sufficient to curve it back. The gun 22 is preferably disposed above the surface of the container so as to provide for adequate room within which the electron beam may be deflected in the desired curved trajectory by the magnetic field. Here again, the electron beams employed for bombarding the bar stock are initially directed into a concave magnetic field and thence pass into a convex magnetic field in the vicinity of actual bombardment, and as a consequence of the foregoing, a highly desirable focusing effect is obtained upon the beams in planes laterally of the direction of propagation of same. By the positioning of the electron guns 22 and 22' adapted to bombard the bar stock 18 laterally outward of the container 14 and bar stock, it will be seen that same are disposed generally outside of any areas of large vapor or gas concentrations. In particular, the lower surface or leading edge 18' of the bar stock, which is bombarded for initial melting of the material, will be seen to be directed toward the open top of the container 14 and not toward the electron guns providing the bombarding electrons. This is highly desirable, inasmuch as instantaneous gas bursts which occur at this bombarded surface 18' will normally travel generally perpendicularly thereto, and consequently, will not approach the electron guns to thereby affect the operation of same.

It is to be appreciated that the electron beam furnace improved by the present invention may employ either horizontal or vertical feed of material to be operated upon therein. In the instance wherein a horizontal feed of material is employed, the present invention is equally applicable in providing for magnetic guidance of bombarding electrons onto the leading surface of the bar stock adapted to be melted for dripping into the mold. Such horizontal feed of bar stock is highly advantageous in the instance wherein such stock may, for example, be formed of pressed powder or other composition, which is not readily handled in a vertical position but is preferably disposed upon a trough or table so as to support the weight of same without relying upon structural strength of the bar stock itself. A portion of a furnace employing bombardment heating and melting of bar stock fed horizontally into the furnace is shown in FIG. 6, wherein a bar stock 51 is shown to be disposed upon a bar trough, or the like 52, extending laterally toward the container 14 above same. Considering FIG. 6 as being taken in the same plane as FIG. 5, it will be seen that an electron gun 22, disposed laterally outward of the container and in this instance below the bar trough 53 projects an electron beam 21 perpendicularly into the magnetic guidance field directed into the plane of the figure. Such magnetic field will exert a deflecting force upon the electron beam so as to curve the trajectory of same to the left and upwardly in the illustration and thence back onto the leading edge 51' of the bar stock. Although but a single horizontal feed is illustrated in FIG. 6, it will be appreciated that material to be treated may be fed horizontally into the furnace from both sides thereof in the plane of FIG. 6, inasmuch as an additional electron gun disposed to the left of the container 14 in this figure will have the electron beam thereof likewise deflected upwardly in the same manner as illustrated and described in connection with FIG. 5 above.

In FIG. 7 there is illustrated in somewhat greater detail an electron beam furnace employing horizontal feed for material to be treated in the furnace, and referring to this figure there will be seen to be provided the furnace enclosure 11 defining an internal chamber 12 which is evacuated by pumping means 13. In common with the above-described furnace of FIG. 1, there is provided a container 14 within the chamber 12 for receiving molten material and solidifying same therein. As such material is solidified within the container 14, it may be withdrawn from the lower end of the container by withdrawal means 17, and suitable cooling passages are provided in the container for removing heat from the material as it is lowered therein. In this particular furnace configuration there is provided a generally horizontal trough 53 adapted to carry a bar stock 51 thereon, and suitable feed means 54 engage this bar stock to move same laterally over the top of the container 14.

Magnetic guidance means are provided in this embodiment of the furnace, similar to that illustrated and described above, and may, for example, include quadrature

magnet poles, such as illustrated in FIG. 2. Considering the illustration of FIG. 7 to be taken in the plane 4—4 of FIG. 3, there will thus be seen to be provided a north pole 42 to the right of the figure and a south pole 41 to the left thereof, with the bar trough and bar stock disposed on the viewing side of the north pole 42. Consequently, in the area of the leading edge 51' of the bar stock there will be seen to be established a magnetic field 52 directed out of the plane of the figure. In this embodiment there is disposed an electron gun 56 above the bar stock 51 in the right-hand quadrant of the furnace, and laterally outward from the container 14. This electron gun generates a high-energy electron beam and directs same somewhat radially inward of the container well above same. Such electron beam 57 will thus be seen to be directed into a magnetic field at right angles thereof, and to thus be operated upon by a deflecting force which will tend to curve the beam trajectory downward. By the appropriate positioning of the electron beam source and bar stock, as well as by the utilization of suitable magnetic field strength and electron beam velocities, this deflection may be made to curve the electron beam, at least in part, upon the leading edge of the bar stock. The electron beam 57 will thus be seen to bombard this leading edge, and consequently to heat same whereby the material of the bar stock is melted to drip downwardly into the mold 14. Bombardment of the material within the mold to maintain a molten pool 26 of material therein may be accomplished in the same manner as described above, by the provision of a pool electron gun 58 disposed below the surface of the pool and laterally outward of same in the opposite quadrant from the bar electron gun 56. This pool gun generates a high-energy electron beam 59, and directs same generally upwardly into the magnetic field directed into the plane of the figure in such quadrant. This electron beam will thus be deflected by the force generated from the moving charges in a transverse magnetic field, so as to assume a trajectory somewhat as illustrated, whereby the beam curves to the right in the figure and back down onto the material in the container 14. The illustrations of FIGS. 6 and 7 are both exemplary of the application of the present invention to electron beam furnaces employing horizontal melt stock feed.

In accordance with this invention as described with reference to particular preferred embodiments thereof above, there is generated magnetic guidance fields extending circumferentially about the axis of the furnace container with different circumferential directions in different portions or segments of the field circumference. In particular, the invention contemplates the provision of at least two different guidance fields which may, however, be generated from a single magnet means, as by the utilization of "image iron" or the like to form a three-pole magnet structure. By the establishment of such a plurality of generally circumferential magnet guidance fields of different directions about the circumference of the container, there is herein provided positions for both pool bombardment and bar stock bombardment, wherein the bombarding means are wholly dislocated from regions of contamination. Not only does the guidance means of the present invention provide a highly desirable focusing and directing effect upon the electron beams, but furthermore, these effects are achieved from beam generation positions which are quite protected, and consequently, which provide for the maximum longevity and highly advantageous operability and control of the electron guns of the furnace. This is of particular importance in an electron beam furnace such as the type herein contemplated, inasmuch as such furnaces are capable of casting and purifying materials in large quantities. Thus, in the casting and purification of refractory metals, such as zirconium or tantalum, for example, quite large ingots of the metal are cast and very large quantities of material are passed through the furnace in relatively short periods of time. Despite the utilization of very high-speed and efficient pumping means in connection with the furnace, it has been found that the substantial quantities of vapors and gases evolved during furnace operation are highly deleterious to the continued operation and control of the electron beam sources employed in the furnace. By the utilization of particular magnetic guidance means, such as those set forth herein, it is possible to materially improve furnace operation by the utilization of maximum amount of energy provided in the electron beams, and furthermore, by the maximum protection of the electron guns. The present invention is in no way limited to the employment of quadrature guidance means, but is directed to the provision of a plurality of guidance fields or field directions, whereby separate portions of the container circumference or periphery are available for pool and bar electron guns, so that the guns are maintained out of line with portions of the material being operated upon within the furnace.

What is claimed is:

1. An electron beam furnace comprising a container having an open top, means feeding a bar of material to be melted toward said container above same, magnetic guidance means generating a magnetic field having lines of force extending circumferentially about the top of said container, and a pair of electron guns displaced laterally from said container and projecting high-energy electron beams perpendicularly into said magnetic field for deflection of one beam onto said bar of material and the other into top of said container whereby material is melted from the bar to drip into the container and is therein further heated.

2. An electron beam furnace as set forth in claim 1, further defined by means supporting said bar of material and moving same laterally toward the container over the top of same, a first of said electron guns being disposed beneath the top of said container and laterally outward from same for directing a high-energy electron beam upwardly into the magnetic guidance field wherein same is deflected to traverse a curved trajectory downwardly into the open top of the container, and the second of said electron guns being displaced laterally from said container and above the feed means of the furnace for directing a high-energy electron beam downwardly into the magnetic guidance field wherein such beam is, at least in part, deflected to impinge upon the leading edge of the bar of material being fed over the container so as to bombard same and melt the material to drip downwardly into the container wherein such material is further heated by electron beam bombardment.

3. An electron beam furnace as set forth in claim 1, further defined by feed means supporting said bar of material and moving same laterally toward said container over the top of same, said magnetic guidance means generating a magnetic field having lines of force extending about the top of said container in opposite circumferential directions in separate circumferential segments of the field, a first of said electron guns being disposed laterally of said container and below the upper surface thereof for directing a high-energy electron beam upwardly into said magnetic guidance field for deflection to traverse a curved trajectory downwardly into the open top of the container, and the other of said electron guns being displaced laterally of said container for directing a high-energy electron beam into said magnetic guidance field in a segment of different field direction for deflection of the electron beam upwardly to traverse a trajectory curving onto the leading edge of the laterally fed bar of material for bombardment of same, whereby such material is progressively melted to drip downwardly into the open top of the mold and therein be further heated by electron bombardment.

4. An electron beam furnace comprising an evacuated enclosure encompassing a container having an open top, means feeding material toward the open top of said con-

tainer above same, magnetic guidance means establishing magnetic lines of force circumferentially about the top of said container, a first source of high-energy electrons laterally displaced from said container above same and directing an electron beam radially inward of the container perpendicularly to said lines of force for deflection thereby onto the front of said material, and a second source of high-energy electrons laterally displaced from said container below the top of same and directing a beam of electrons upwardly for deflection in a curved trajectory by said lines of force into the open top of said container to bombard material dripped therein from said material fed over the container.

5. An electron beam as claimed in claim 4, further defined by said sources of electrons being displaced from each other circumferentially about said container.

6. An electron beam furnace as claimed in claim 4, further defined by said magnetic guidance means establishing magnetic lines of force in different circumferential directions in different segments of the circumference, and said electron sources being disposed in different circumferential segments whereby one beam is deflected upwardly and the other downwardly.

7. An electron beam furnace as defined in claim 4, further characterized by said magnetic guidance means establishing a magnetic field having lines of force extending in opposite circumferential directions in adjacent quadrants about the top of said container, said first source of high-energy electrons being disposed in such quadrants of said magnetic guidance field that the projection of electrons therefrom perpendicularly into the field produces a deflecting force upon the electrons urging same upwardly from the container for bombardment of the material thereabove, and said second source of high-energy electrons being disposed in alternate quadrants of said magnetic field whereby direction of the electrons therefrom perpendicularly into the field produces a deflecting force thereon urging the electrons downwardly into the open top of the container.

8. An electron beam furnace comprising an enclosure defining an evacuated chamber, an open-topped container within said chamber for receiving molten material operated upon within the furnace, means feeding a material toward the open top of said container above same, a plurality of magnet pole pieces disposed about the circumference of said container adjacent the top thereof, means energizing at least two of said pole pieces to establish magnetic guidance fields extending substantially circumferentially of said container about the top thereof and having different directions in different segments of the circumference, first electron source means directing high-energy electrons into said magnetic guidance field substantially perpendicularly thereto for deflection thereby into curved trajectories extending upwardly of the container into focus upon the leading surface of said material fed toward the container for bombardment heating and melting of said material so that same drips downwardly into the open top of said mold, and second electron source means directing high-energy electrons into said magnetic guidance field in segments of opposite direction thereof, generally perpendicularly to the field for deflection thereby into curved trajectories terminating in the open top of the container for bombardment heating of material dripping therein.

9. An improved electron beam furnace comprising an enclosure defining a chamber, means continuously evacuating said chamber, a container within said chamber and having an open top for receiving molten material treated within the furnace, feed means moving a bar of material toward the open top of said container above same, four magnet pole pieces disposed in quadrature relationship about the top of said container with alternate polarity poles, means energizing said pole pieces to establish magnetic guidance fields about the top of said container, a first plurality of electron guns disposed radially outward of said container in opposite quadrants and directing high-energy electron beams perpendicularly into the magnetic guidance fields of opposite quadrants whereby the fields deflect said electron beams in curved trajectories into focus upon a leading surface of material being fed over the container for bombardment heating of same, and a second plurality of electron guns disposed radially outward of said container in quadrants intermediate the first plurality of electron guns for directing high-energy electron beams into the magnetic guidance fields substantially perpendicularly thereto for focusing by the fields into the open top of the container to bombard and further heat material dripped therein as a result of the bombardment heating by said first plurality of electron guns.

10. An improved electron beam furnace as defined in claim 9, further characterized by said magnetic guidance means including a pair of magnet yokes having two pole faces each and disposed about the circumference of said container above the top of same in equal circumferential spacing, means energizing said magnet yokes to establish magnetic flux therethrough with said flux being directed to establish magnetic poles of opposite polarity alternating about the circumference of said container, the magnetic field established by the foregoing and extending between said pole pieces having a convex configuration from positions laterally outward of the container for focusing electrons directed substantially perpendicularly into the field, whereby a maximum amount of electrons so directed are constrained to bombard material within the furnace.

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